621.3206
Il
Engri.
06

LIBRARY OF THE
APR 30 1957
UNIVERSITY OF ILLINOIS

TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909

INCORPORATED 1930

CONTENTS

	Page
Report of the Council - - - -	87
Additions to the List of Members - -	104
A Method of Calculating Flux from an Isocandle Diagram Using a System of Discrete Points, by Doreen Smith, B.Sc. -	105

VOLUME 22
No. 4 — 1957

32 VICTORIA ST
LONDON, SW1

Annual Subscription to Non-Members - £2.2.0
Price per Number to Non-Members - 5s. 0d.

The I.E.S. Council and Committees

Session 1956-1957

Council

President :—W. E. HARPER, B.Sc. (Eng.), Ph.D. (*Fellow*).

Vice-Presidents :— R. G. HOPKINSON, B.Sc. (Eng.), Ph.D. (*Fellow*), J. S. MCCULLOCH (*Fellow*), E. B. SAWYER (*Fellow*), C. C. SMITH (*Fellow*), W. T. F. SOUTER (*Fellow*).

Members of Council :—

Elected Members :—
D. S. ALLOM, A. D. S. ATKINSON, H. H. BALLIN, D. E. BEARD, C. R. BICKNELL, H. G. CAMPBELL, H. CARPENTER, J. B. COLLINS, H. F. GILLBE, A. W. GOSTT, J. B. HARRIS, G. E. V. LAMBERT, A. H. OLSON, A. POTT, W. E. RAWSON-BOTTOM, J. REID, N. C. SLATER, G. C. SMALL, J. S. SMYTH, J. F. STANLEY, W. J. P. WATSON, H. E. G. WATTS, A. WILCOCK, A. H. YOUNG.

Ex-Officio Representatives of Centres :—
H. A. TURNER (*Bath and Bristol*), V. A. HEYDON (*Birmingham*), J. D. CALLAWAY (*Cardiff*), E. CASSIDY (*Edinburgh*), E. T. RADFORD (*Glasgow*), R. V. PARSONS (*Gloucester and Cheltenham*), W. L. J. POTTS (*Leeds*), C. P. WESTON (*Leicester*), F. J. BURNS (*Liverpool*), T. L. ROBINSON (*Manchester*), P. S. J. UNDERWOOD (*Newcastle*), G. F. G. KING (*Nottingham*), F. A. BENSON (*Sheffield*), T. S. HARPER (*Transvaal*).

Hon. Treasurer :—
W. ROBINSON.

Hon. Secretary :—
J. G. HOLMES.

Hon. Editor of Transactions :—C. R. BICKNELL, B.Sc.

All Past-Presidents of the Society are *ex-officio* Members of Council.

Committees

GENERAL PURPOSES COMMITTEE: W. E. Harper (*President*), A. G. Higgins (*Past-President*), R. G. Hopkinson, J. S. McCulloch, E. B. Sawyer, C. C. Smith, W. T. F. Souter (*Vice-Presidents*), W. Robinson (*Hon. Treasurer*), J. G. Holmes (*Hon. Secretary*), H. A. Turner (*Bath and Bristol Centre*), F. A. Benson (*Sheffield Centre*).

PAPERS COMMITTEE: D. S. Allom, H. H. Ballin, H. Carpenter, J. B. Harris, G. E. V. Lambert, A. H. Olson, G. C. Small, W. R. Stevens, A. H. Young.

EDUCATION COMMITTEE: A. D. S. Atkinson, D. E. Beard, W. E. Rawson-Bottom, J. Reid, J. F. Stanley, W. J. P. Watson.

CODE COMMITTEE: R. G. Hopkinson, A. G. Penny, A. Pott, W. R. Stevens, H. C. Weston.

CENTRES JOINT COMMITTEE: One representative from each Centre and the five Vice-Presidents.

AWARDS JUDGING COMMITTEE: H. H. Ballin, G. E. V. Lambert, C. C. Smith, W. R. Stevens, C. R. Bicknell.

(The President, Hon. Secretary and Hon. Treasurer are *ex-officio* members of all committees.)

Secretary : G. F. COLE, 32, Victoria Street, London, S.W.1.

Report of the Council

(January 1—December 31, 1956)

The Council has the honour to present its report upon the affairs of the Society during the year ended December 31, 1956, this year being the forty-eighth in the life of the Society.

This report is set in a form somewhat different from previous reports in order to direct attention to the extensive work within the Society. Although Council is responsible for the work of the Society, much of it necessarily devolves upon its committees whose members Council warmly thanks for the time and thought they have given throughout the year to the affairs and welfare of the Society.

Council

The year has been an arduous one for Council, involving many matters important to the future of the Society. Prominent among them have been the revision of the constitution and consideration of a possible change in the Society's name.

As long ago as March, 1955, the General Purposes Committee reported that the Memorandum and Articles of Association of the Society drawn up in 1930 needed revision to bring them into line with the Companies Act, 1948, to remove various sections which, though pertinent at the time of incorporation of the Society, are now redundant, and to take into account developments within the Society since 1930. Council received this report and instructed the General Purposes Committee to take legal advice. This it did and submitted its first recommendations to Council in October, 1955. In making this report the General Purposes Committee stated that its consideration of the constitution, and in particular that section of the Memorandum of Association dealing with the objects of the Society, led it to doubt whether the Society's name adequately expressed its present work and interests; the committee therefore recommended that a change in name be considered.

Throughout the year under review these matters have been discussed at length and with great care both in Council and with the Society's legal advisers. The outcome of this work has been the preparation of a new constitution which has been accepted by Council and approved by the Board of Trade and which will be submitted to members at an Extraordinary General Meeting to be held on March 26, 1957. It is not possible in this report to comment in detail on the new constitution but reference is appropriate to one of its provisions. Dissatisfaction had been expressed for some time with the title "Registered Lighting Engineer", for those members holding professional qualifications and more suitable titles were discussed. In the past the terms of the constitution imposed certain restrictions on the titles possible, but the Board of Trade has given permission under the new constitution for the Society to create a special class of members to be known as "Diploma Members" and for the use of appropriate initials by them. Those members at present included on the Register will qualify for inclusion in this new class of member.

On the matter of change in name of the Society, while Council has recognised the force of the arguments for a change, it has throughout realised the very considerable goodwill bound up with the present name and has stood by a policy that a change should be effected only if a large majority of members approve the proposal. In order to ascertain the general opinion of the Society the Council held a referendum in October when the alternative name of "The Lighting Society" was submitted for the consideration of members. This name was selected only after discussion of many alternatives that were suggested and was adopted as a name that was simple, direct

To be presented at the Annual General Meeting of the Society, to be held at the Royal Society of Arts, John Adam Street, London, W.C.2, at 5.30 p.m. on Tuesday, May 14, 1957.

and comprehensive. There was a very large response to the referendum which showed that a majority of members were in favour of a change. Council therefore decided that the issue should be put to a formal vote at the Extraordinary General Meeting in March, 1957.

Throughout the long and intricate discussions on the revised constitution, the Council has had at its service the legal advice and experience of the immediate Past-President, Mr. A. G. Higgins. The Council is indebted to Mr. Higgins for his work during the past two or three years and places on record its gratitude for his many services.

At the beginning of each year the Council receives the Honorary Treasurer's estimates on income and expenditure for the forthcoming year. The estimates for 1956 showed that owing to many rising costs a deficit of the order of £800 was probable and Council therefore decided with regret that it would be necessary to recommend an increase in the rates of annual subscription, which, it should be pointed out, had not been raised since 1945. Resolutions amending the by-laws relating to subscriptions were submitted to an Extraordinary General Meeting held at Harrogate in May and were approved. The new rates of subscription became effective on January 1, 1957. At the same meeting it was agreed to discontinue the class of Overseas Member owing to the uneconomic subscription rate, and Council is glad to report that nearly all Overseas Members have now transferred to Corporate membership and thanks them for this expression of their confidence.

In view of the probable deficit Council was obliged throughout 1956 to restrict expenditure with a consequent restraint in the development of some activities of the Society. With increased revenue in coming years the Council hopes that the Society will be able to widen its activities and improve its service both to members and to the community as a whole and is now planning to that end.

At the request of the Centres Joint Committee, Council is considering a revised scheme of financial allocation to Centres designed to give greater help to the smaller Centres. If approved the new scheme will come into operation in 1958, but in the meantime Council has approved an additional grant to all Centres for 1957, feeling that the Centres should receive some immediate benefit from the higher income expected this year

During the year the report of the Committee set up under the chairmanship of Dr. W. J. Wellwood Ferguson to consider eyestrain in cinemas was presented to Council and approved for publication. The work done by this committee is of considerable value to the cinema industry and has brought credit to the Society. The Council thanks all who took part in the work.

An essay competition for the Dow Prize was held during the year, entries being restricted to members of the Society. Prizes were awarded to R. W. Taylor, C. Stuart and D. Phillips.

In 1959 the Society will celebrate its Jubilee and Council has approved in principle provisional recommendations on the form of the celebrations submitted by the General Purposes Committee.

No nominations to the vacancies for officers and members of Council were received additional to those made by Council and circulated to Corporate Members, and the following were therefore elected and took office in October:—

President: Dr. W. E. Harper.
Vice-Presidents: Dr. R. G. Hopkinson, Mr. J. S. McCulloch, Mr. E. B. Sawyer, Mr. C. C. Smith, Mr. W. T. F. Souter.
Hon. Treasurer: Mr. W. Robinson.
Hon. Secretary: Mr. J. G. Holmes.
Hon. Editor of the Transactions: Mr. C. R. Bicknell.

Ordinary Members of Council: Mr. A. D. S. Atkinson, Dr. H. H. Ballin, Mr. D. E. Beard, Mr. H. G. Campbell, Mr. J. B. Harris, Mr. A. Pott, Mr. G. C. Small, Mr. J. F. Stanley.

The following were appointed to represent their respective Centres on the Council for the Session 1956-57:—

Bath and Bristol: Mr. H. A. Turner. *Birmingham*: Mr. V. A. Heydon. *Cardiff*: Mr. J. D. Callaway. *Edinburgh*: Mr. E. Cassidy. *Glasgow*: Mr. E. T. Radford. *Gloucester and Cheltenham*: Mr. R. V. Parsons. *Leeds*: Mr. W. L. J. Potts. *Leicester*: Mr. C. P. Weston. *Liverpool*: Mr. F. J. Burns. *Manchester*: Mr. T. L. Robinson. *Newcastle*: Mr. P. S. J. Underwood. *Nottingham*: Mr. G. F. C. King. *Sheffield*: Dr. F. A. Benson. *Transvaal*: Mr. T. S. Harper.

In October Mr. A. Wilcock was appointed to fill a casual vacancy until September, 1957.

General Purposes Committee

The General Purposes Committee of the Council deals with questions of administration and general policy of the Society which may be referred to it by the Council or to which the committee may wish to draw the attention of Council, and to deal with matters which, on account of urgency or expediency, cannot first be considered by Council. In effect this means that the General Purposes Committee frequently has the task of examining in detail matters which are later referred to Council for a decision. Much of the detailed and intricate work connected with the revision to the constitution was dealt with by the committee in this way and considerable time has been given to these matters.

Other matters which are referred to in greater detail elsewhere in this report and which have been before the committee include the development of membership, the improvement in the Society's *Transactions*, the arrangements now being made for celebration of the Society's Jubilee in 1959, the formation of a Technical Committee, the basis of financial allocation to Centres, the Honorary Treasurer's estimates of income and expenditure for the year and the future use of the Dow Legacy Fund.

Regarding this last matter, the use of the income from the fund to provide a prize for a competition has not proved as successful as was hoped and the committee has been instructed by Council to investigate other possible uses of the fund to the better advantage of the Society and members and to provide a more worthy memorial to J. S. Dow.

At the request of Council the General Purposes Committee also reviews from time to time the arrangement with the Illuminating Engineering Publishing Co., Ltd., for the supply of the journal *Light and Lighting* to members. With the considerable increase in the cost of publishing which has taken place in recent years it was inevitable that the Society would be called upon to pay more for the journal. At the same time the contents and format of the journal itself have been much improved, improvements which have necessarily incurred additional costs. In these matters the General Purposes Committee has maintained close liaison with the Illuminating Engineering Publishing Co., Ltd., and during the past year has reported that the existing arrangement between the Society and the Publishing Company is the best that is possible under present conditions. The committee, and also the Council, has the firm opinion that the high standard set by *Light and Lighting* should not be lowered; Council feels that members will agree with this and congratulate the publishers on the excellence of the journal.

Relating to the future development of the Society, the committee, as already mentioned, has been considering the question of setting up a Technical Committee to extend

the technical service provided by the Society. Proposals on the formation of the committee have been prepared for submission to the Council.

The members of the General Purposes Committee consist of the President, the immediate Past-President, the Vice-Presidents and officers and two representatives of the Centres; during the present session Mr. H. A. Turner, of Bath and Bristol, and Dr. F. A. Benson, of Sheffield, are the Centres' representatives.

Membership

During the year many new applications for membership were considered and approved by the Council, but owing to deaths, resignations and other causes the total number of members at the end of the year showed a decrease of 39. Details of membership at the end of the year under review are given in the table.

It was with regret that the Council noted the death of Mr. J. F. Colquhoun, who had been a most enthusiastic member since he joined the Society in 1931.

In order to increase the membership of the Society the General Purposes Committee appointed a Membership Sub-Committee. Under the chairmanship first of Mr. A. H. Olson and now of Mr. A. W. Gostt, this sub-committee has been responsible for obtaining more than 20 new Sustaining Members as well as a number of new Corporate Members during the year. So far the sub-committee has concentrated its efforts on obtaining new members from within the London area, but co-operation with the Centres will now be sought in an effort to expand membership in other parts of the country. During its approach to prospective members the sub-committee has found that there are many companies and individuals in the lighting industry who have not previously understood or appreciated the work of the Society. The committee therefore asks that all members use every opportunity to explain the work and claims of the Society and feels that it is not unreasonable to assume that every member could introduce at least one new member.

The Membership Sub-Committee is also considering means of improving publicity given to the Society and its activities throughout the country.

A list of Sustaining Members is attached to this Report. In thanking them for their continued support the Council records its appreciation to Sustaining Members who, in response to the Society's request for increased funds to enable its work to continue and to expand, have voluntarily increased their annual subscriptions, in many cases most generously.

Fellowship and Registration Board

The Fellowship and Registration Board is responsible on behalf of Council for considering applications for Fellowship and for inclusion in the Register of Lighting Engineers. During 1956 the election of three new Fellows (Mr. D. W. Durrant, Dr. V. G. W. Harrison and Mr. J. S. McCulloch) and inclusion of the names of eight Corporate Members on the Register of Lighting Engineers were approved by the Council. There are now 157 Fellows and the Register includes the names of 250 Corporate Members of the Society.

The board considered and supported the recommendation of the Education Committee that the examination qualification for inclusion in the Register be raised to a Final Certificate in Illuminating Engineering of the City and Guilds of London Institute.

Awards Judging Committee

The Awards Judging Committee, the members of which at the time were Mr. J. Reid, Mr. N. C. Slater, Mr. J. M. Waldram, Mr. D. A. Strachan, Mr. W. Robinson and Mr. C. R. Bicknell, recommended to Council that the Leon Gaster Memorial Premium for the best paper presented to and published by the Society during the year, be

Total Membership
(As at December 31, 1956)

	Fellows	Corporate Members	Overseas Members	Students	TOTAL	Sustaining Members
London... ...	98	666	—	41	805	64
Centres :—						
Bath & Bristol	3	52	—	—	55	2
Birmingham ...	8	212	—	4	224	26
Cardiff... ...	3	64	—	2	69	2
Edinburgh ...	4	37	—	—	41	4
Glasgow ...	4	69	—	1	74	7
Gloucester & Cheltenham ...	—	30	—	—	30	—
Leeds	5	184	—	16	205	6
Leicester ...	2	34	—	—	36	—
Liverpool ...	2	110	—	2	114	8
Manchester ...	3	147	—	2	152	12
Newcastle ...	4	91	—	—	95	5
Nottingham ...	3	73	—	3	79	1
Sheffield ...	2	58	—	3	63	1
Transvaal ...	3	58	—	2	63	15
Groups :—						
N. Lancashire...	2	39	—	—	41	—
Stoke-on-Trent	—	25	—	—	25	—
Swansea ...	—	22	—	—	22	—
Tees-side ...	—	21	—	—	21	—
Ireland	2	25	—	—	27	—
Overseas ...	9	120	88	1	218	2
TOTAL ...	157	2137	88*	77	2459	155

* This class of membership is discontinued as from January 1, 1957

awarded to Mr. D. W. Durrant for his paper entitled "Decorative Lighting—A Designer's Approach." The award was made at the opening sessional meeting in October.

No entries were received during 1956 for the Silver Jubilee Commemoration Award.

Code Committee

A new edition of the I.E.S. Code was published in 1955. Although possible revisions to the Code are constantly reviewed by the Code Committee there is no intention for the time being of issuing a further edition. The committee is, however, considering possible extensions of the information given in the Code, but as yet it is too early to say what form these might take.

The membership of the Code Committee at the end of the year was: Dr. W. E. Harper (chairman), Dr. R. G. Hopkinson, Mr. A. G. Penny, Mr. A. Pott, Mr. W. R. Stevens and Mr. H. C. Weston.

Papers Committee

The Papers Committee is responsible for arranging the London sessional meetings and approving papers to be published in the *Transactions* which are themselves the record of the committee's work. In considering papers for presentation and/or publication the committee submits each contribution to referees whose comments are of value to the committee, to the authors of papers and to the Editor; the opportunity is taken of thanking those who have acted as referees during the past year.

The committee quite properly places great emphasis on the quality of material presented to the Society and the task of suggesting or selecting papers which together will make a balanced programme is not an easy one. To ensure good discussion of papers authors are asked to submit their manuscripts four months before the date of the meeting at which they are to be presented. Few authors, unfortunately, appreciate that this time is essential if manuscripts are to be refereed, amended where necessary by the author, edited and set in type to permit the circulation of copies well before the meeting. On a number of occasions during the year manuscripts were received too late for pre-prints to be issued and as a result the discussions on those papers were not as constructive as they could have been.

The committee has been conscious for some time that though the content of the *Transactions* is of a high standard the physical presentation leaves much to be desired. The present small size of the *Transactions* was forced upon the Society by the economies necessary during the war and by continually rising prices ever since. At the beginning of the year the committee, at that time under the chairmanship of Mr. H. G. Jenkins, looked further into the possibility of improving the *Transactions* and submitted proposals to the General Purposes Committee which were considered and subsequently approved by Council. From January, 1958, the *Transactions* will be printed on paper of better quality, in the pre-war size, with an improved cover and will be published quarterly. The *Transactions* not only record the proceedings of the Society and work carried out in many branches of the lighting profession, they also uphold the status of the Society in this and other countries.

The Society is indebted to the Lighting Service Bureau for facilities made available to the Society for the holding of many meetings. Meetings were also held at the Royal Institution and at the Federation of British Industries.

The membership of the Papers Committee at the end of the year was as follows: Mr. W. R. Stevens (chairman), Mr. D. S. Allom, Dr. H. H. Ballin, Mr. H. Carpenter, Mr. J. B. Harris, Mr. G. E. V. Lambert, Mr. A. H. Olson, Mr. G. C. Small, Mr. A. H. Young. Co-opted: Mr. P. H. Collins and Mr. J. T. Grundy.

Summer Meeting Committee

A committee under Mr. H. G. Campbell as chairman was appointed to organise the 1956 Summer Meeting which took place at Harrogate from May 8 to 11. Other members of the committee were Mr. N. Boydell, Mr. E. S. Evans, Mr. A. G. Penny, Mr. D. A. Strachan and Mr. H. E. G. Watts. Mr. A. H. Nash was co-opted to the committee to make the arrangements for the display of new lighting equipment. The committee had throughout the co-operation of the Leeds Centre.

The attendance of 411 was approximately the same as at the 1954 Summer Meeting. The Society is always pleased to see visitors from other countries at these meetings and was happy on this occasion to welcome visitors from 11 overseas countries including two members of the Transvaal Centre.

The meeting began with a series of visits to factories in Yorkshire followed in the evening by a reception given by the Harrogate Corporation. After the official opening by the Mayor of Harrogate on the following morning, a paper entitled "Light and Colour in Daily Life" was presented by Dr. J. W. Strange and Mr. H. Hewitt. During

the afternoon two papers of particular interest to those concerned with the installation and maintenance of lighting were given by Mr. J. S. McCulloch who dealt with "Lighting in Standard Factories on a Trading Estate," and by Mr. J. Mortimer Hawkins and Mr. C. J. Veness whose paper was entitled "A Critical Analysis of Lighting Equipment and its Maintenance." The Thursday morning was devoted to further factory visits and in the afternoon two distinguished visitors from overseas presented papers: Prof. L. Schneider on "New Lighting Development in Germany" and Mr. J. Havelka on "Lighting Developments in Czechoslovakia." The papers on the final morning were "Relative Brightness of Coloured Light Sources" by Mr. W. R. Stevens and Mr. H. M. Ferguson, and "Decorative Lighting—A Designer's Approach" by Mr. D. W. Durrant. It was generally agreed that the papers were of a very high standard and the best series yet presented at a Summer Meeting. The discussion on all papers was both stimulating and instructive.

Following the successful experiment at the 1954 meeting, a display of new lighting equipment was again arranged and proved a most popular feature. Thanks are due to Mr. A. H. Nash who arranged the display and to the Harrogate Sub-Area of the North-Eastern Electricity Board which provided help and facilities for erection. The display was opened on the Wednesday evening by Dr. J. W. T. Walsh, President of the International Commission on Illumination.

Dr. Walsh was also the guest of honour at the annual dinner held on the Thursday evening, when over 300 members and guests were present. As President of the CIE Dr. Walsh proposed the toast of the Society, to which the President, Mr. A. G. Higgins, responded. The toast of the guests was proposed by Mr. H. G. Campbell, the reply being made by the Mayor of Harrogate.

The Council wishes to express its appreciation, and also that of all who were present at Harrogate, to the Summer Meeting Committee, to the Papers Committee, the Leeds Centre and to all others who helped to make the meeting the success it undoubtedly was. Arrangements are now being made for the next Summer Meeting, which will be held at Eastbourne from May 11 to 14, 1958.

Education Committee

It is the responsibility of the Education Committee to consider all matters relating to the education and training of the lighting engineer and any other matters concerning education referred to the Society. The Society does not itself arrange courses for the City and Guilds examinations, but the committee endeavours to arrange through the technical colleges for such courses to be held. As mentioned in previous reports, owing to the small number of students and their distribution around the country it is very difficult for colleges other than those in London to arrange such courses. This difficulty still remains though it would appear that many provincial students are taking advantage with success of the correspondence courses which are available. The number of successful candidates in the City and Guilds examinations in 1956 showed a slight increase over the previous year, there being 27 successes in the intermediate grade, and in the final examination 13 in papers 1 and 2 and 14 in papers 1 and 3.

During the year the committee, through the Society's representative, made suggestions to the City and Guilds Advisory Committee on Illuminating Engineering on the questions set in the intermediate examination, and it is understood that these suggestions are being considered.

The acceptance of the Intermediate Certificate in Illuminating Engineering of the City and Guilds of London Institute was always regarded as an interim step in the development of the Register of Lighting Engineers and in establishing a professional qualification. A recommendation that as from October, 1957, the examination qualification for inclusion in the Register be a Final Certificate instead of the Intermediate Certificate was made to Council and approved. In making this recommendation

the committee had in mind that the majority of applicants for inclusion in the Register held one or both of the Final Certificates. Further, the Institution of Electrical Engineers had now introduced lighting as an optional subject in its own examinations to a standard approximately equal to the Intermediate examination; it was considered that the professional standard of our own Society should be higher.

It was mentioned in the last Report that a number of Schools of Architecture had sought the assistance and advice of the Society in teaching lighting to students of architecture and that the Education Committee was looking into the matter. The committee decided after careful consideration that the subject could best be taught by the existing staff of the schools rather than by visiting lecturers. It proposed that the Society should hold a briefing course of three days' duration to which one representative from each school would be invited. A programme has been outlined and discussed with the RIBA, but agreement on the details has yet to be reached. Although it now seems unlikely that it will be possible to hold the course during 1957 as originally intended, it is hoped that the scheme will go forward and will further co-operation between the two professions.

To much the same end, a series of four weekly lectures on architecture for members of the Society has been given by Mr. John Reid and was very well supported, the average attendance being 70 to 80. The Council thanks Mr. Reid for the work he put into these lectures, and Holophane Ltd., who placed their lecture theatre at the disposal of the Society. The committee is now considering the possibility of organising a similar course of lectures during 1957.

During the year the Education Committee revised the standard lecture to schools and prepared a short statement on illuminating engineering as a career. At the present time the committee has before it the teaching of lighting (other than courses for the City and Guilds examinations) to engineering students at technical colleges and universities, and the arrangement of one-day conferences on different aspects of lighting for different types of users.

The chairman of the Education Committee during the year was Mr. C. Dykes Brown and the following were members at the end of the year: Mr. A. D. S. Atkinson, Mr. D. E. Beard, Mr. W. E. Rawson-Bottom, Mr. J. Reid, Mr. J. F. Stanley, and Mr. W. J. P. Watson.

Centres and Groups

Although much of this report is necessarily concerned with events centred at headquarters it cannot be too strongly emphasised that the work is done for the benefit of all members. A healthy Society calls not only for Centres which are vigorous and successful individually, but for that measure of understanding and co-ordination which alone can result in the vigour of the whole body.

In general the Centres and Groups of the Society have had a successful year with good programmes. Council is conscious, however, of difficulties experienced in some of the smaller Centres and hopes that new financial arrangements will help in strengthening and developing the activities of the Society in those Centres. In the meantime it expresses its gratitude to local officers who are maintaining the interests of the Society under conditions which are often far from easy.

A constant concern of Council is to maintain effective liaison between the different sections of the Society and to avoid any sense of isolation. This is achieved in part by the meeting in Council of members from the Centres and by visits to the Centres paid by the President, Vice-Presidents and officers. But these occasions permit little time for conference on matters between Centres and Council is anxious to extend the work and influence of the Centres Joint Committee. Usually the committee meets only once a year in London at the beginning of each Session. Such a meeting took place during October and among the matters discussed were proposals for the development of membership, provisional arrangements for celebration of the Jubilee

in 1959 and the system of financial allocation to Centres. Since that meeting it has become apparent that there are many matters on which an interchange of ideas would be to the good of the Society and a second meeting during this session is to be held at Leeds in the early part of 1957.

The attendance at some Centre and Group meetings is giving concern both to local committees and to Council. Very small attendances are not only discouraging to lecturers, but also damaging to the reputation of the Society. Although this matter may well benefit from discussion in the Centres Joint Committee, the final answer to the problem must lie in the initiative of local Centre and Group committees. The difficulty arises from the comparatively small membership of the Society, and Council appreciates that very often the attendance at meetings, though apparently small, represents a considerable proportion of the available membership—frequently a much higher proportion than that claimed by other bodies who have a much larger membership from which to draw.

At December 31 the Chairmen and Honorary Secretaries of the respective Centres and Groups were as follows:—

	Chairman	*Hon. Secretary*
Bath and Bristol	H. A. Turner	C. W. Rawlings
Birmingham	V. A. Heydon	B. J. McCarthy
Cardiff	J. D. Callaway	G. J. Prothero
Edinburgh	E. Cassidy	C. Couper
Glasgow	E. T. Radford	A. M. Rankin
Gloucester and Cheltenham	R. V. Parsons	F. J. Chappell
Leeds	W. L. J. Potts	J. W. Howell
Leicester	C. P. Weston	A. E. Bird
Liverpool	F. J. Burns	J. L. McCauley
Manchester	T. L. Robinson	E. Axon
Newcastle	P. S. J. Underwood	R. P. Wingate
Nottingham	G. F. G. King	G. C. Small
Sheffield	F. A. Benson	E. G. R. Taylor
Transvaal	T. S. Harper	H. L. Roston
North Lancashire	H. Wilcock	M. Sutcliffe
Stoke-on-Trent	J. S. Beddows	J. P. Oliver
Swansea	G. J. Higgs	S. G. Gorman
Tees-side	G. Cross	P. Rose

Finance

The income of the Society was slightly less than that for the previous year. Income from subscriptions increased, but receipts from sales of publications did not reach the previous year's high figure which included receipts from a new issue of the Code. Expenditure exceeded income by £893 over the year, an indication of the continued adverse trend in costs all round. The increased rate of subscription is expected to balance the budget in 1957, but the estimated surplus leaves small margin for broadening the activities of the Society, making necessary determined efforts to increase the Society's membership. Upon this depends the success of the Society in consolidating and extending its influence in the coming years.

Conclusion

The year has been one of advance in administration rather than in membership or technical programmes. The preparation of the new constitution, the critical examination of the name of the Society, the strengthening of the financial structure; these and many other matters all show the active concern for the policy of the Society and Council is confident that the basic organisation of the Society is suitable for growth in membership and in influence. The keen arguments on the pros and cons of the title of the Society is one sign of great vitality; the increase in Sustaining Member-

INCOME AND EXPENDITURE ACCOUNT

EXPENDITURE

1955				
£		£ s. d.	£ s. d.	
2,149	Administration Expenses :—			
100	Salaries and State Insurance	2,571 14 5		
388	Staff Superannuation Scheme	100 0 0		
73	Rent and Rates	481 14 0		
71	Lighting and Heating	70 15 10		
307	Telephone	88 15 11		
182	Printing and Stationery	549 5 1		
168	Postage	396 9 10		
—	Travelling Expenses	148 14 1		
362	Legal Charges	273 10 0		
3,800	Sundry Office Expenses	384 16 4		
237			5,065 15 6	
1,144	Meetings in London		208 9 8	
37	Expenditure of Centres and Groups		1,343 13 7	
5,218	Audit Fee		36 15 0	
1,372			6,654 13 9	
475	Cost of Printing Transactions, Reprints, etc.		1,627 9 2	
58	Cost of Printing I.E.S Code.		– – –	
–	Expenditure on Annual Dinner *less* Sale of Tickets ...		– – –	
	Expenditure on Summer Meeting *less* Sale of Tickets ...		159 6 1	
	Illuminating Engineering Publishing Co., Ltd.—			
	Cost of " Light and Lighting "	1,849 2 1		
	Less Contribution towards administration expenses ...	500 0 0		
1,446			1,349 2 1	
43	Contributions to Kindred Societies		66 13 0	
8,612			9,857 4 1	
504	Balance, being excess of Income over Expenditure ...		– – –	
£9,116			£9,857 4 1	

BALANCE SHEET

1955				
£		£ s. d.	£ s. d.	
	Capital Account :—			
9,744	Balance at 31st December, 1955	10,248 14 10		
Add 504	*Less* Excess of Expenditure over Income for the year	893 4 7		
10,248		9,355 10 3		
904	*Less* Depreciation of Investments	1,106 14 9		
9,344			8,248 15 6	
	Reserve for Special Expenses :—			
147	Balance at 31st December, 1955	97 15 8		
49	*Less* Repairs to Demonstration Equipment	6 8 0		
98			91 7 8	
283	Creditors		427 1 11	
£9,725			£8,767 5 1	

W. ROBINSON (*Hon. Treasurer*)
J. G. HOLMES (*Hon. Secretary*)

FOR THE YEAR ENDED 31st DECEMBER, 1956

INCOME

1955				
£		£	s.	d.
7,712	Subscriptions and Fees	7,974	10	4
1,141	Sales of publications	694	6	1
263	Interest on Investments	283	18	1
—	Premium on Redemption of Investments	11	5	0
—	Excess of Expenditure over Income	893	4	7
£9,116		£9,857	4	1

31st DECEMBER, 1956

1955								
£	Investments at cost :—		£	s.	d.	£	s.	d.
£2,020 14s. 7d.	3½% War Loan		2,059	15	0			
£1,250	3% Defence Bonds		1,250	0	0			
£250	2½% Defence Bonds		250	0	0			
£1,750	4½% Defence Bonds		1,750	0	0			
£1,500	3% Savings Bonds		1,501	15	3			
£500	3% British Transport Guaranteed Stock		488	4	6			
£1,000	3½% Defence Bonds		1,000	0	0			
£500	Abbey National Building Society ...		500	0	0			
8,799			8,799	14	9			
904	*Less* Depreciation ... ... (*Market Value 31.12.56, £7,693*)		1,106	14	9			
7,895						7,693	0	0
108	Debtors					132	1	0
1,722	Balance at Bankers and Cash in Hand					942	4	1
£9,725						£8,767	5	1

Auditors' Report.—We have examined the above Accounts with books and vouchers, and certify same to be correct in accordance therewith and that the Balance Sheet exhibits a true and correct view of the Society's affairs according to the information and explanations given to us.

ROBERT J. WARD & CO., *Chartered Accountants*,
3, ROBERT STREET, ADELPHI, W.C.

Dated this 11th Day of January, 1957.

RECEIPTS & PAYMENTS ACCOUNTS FOR

LEON GASTER

	£	s.	d.
Balance, 1st January, 1956	251	17	4
War Loan Interest	8	1	0
	£259	18	4

NATIONAL ILLUMINATION

	£	s.	d.
Balance, 1st January, 1956	342	12	1
War Loan Interest	10	10	0
	£353	2	1

INTERNATIONAL ILLUMINATION

	£	s.	d.
Balance, 1st January, 1956	485	10	6
Interest on Investments	14	0	0
	£499	10	6

TROTTER-PATERSON

	£	s.	d.
Balance, 1st January, 1956	365	9	6
Defence Bond Interest	12	5	0
	£377	14	6

JOHN S. DOW

	£	s.	d.
Balance, 1st January, 1956	2,202	8	0
Interest on Investments	69	1	6
	£2,271	9	6

FOR THE YEAR ENDED 31st DECEMBER, 1956

MEMORIAL FUND

	£ s. d.	£ s. d.
Premiums paid		10 10 0
Balance, 31st December, 1956 :—		
Cash at Bank	12 15 2	
£230 3½% War Loan at cost	236 13 2	
(*Market Value 31.12.56, £162*)		249 8 4
		£259 18 4

COMMITTEE FUND

	£ s. d.	£ s. d.
Balance, 31st December, 1956 :—		
Cash at Bank	48 13 7	
£300 3½% War Loan at cost	304 8 6	
(*Market Value 31.12.56, £211*)		353 2 1
		£353 2 1

CONGRESS FUND

	£ s. d.	£ s. d.
Balance, 31st December, 1956 :—		
Cash at Bank	95 2 0	
£300 3½% War Loan at cost	304 8 6	
(*Market Value 31.12.56, £211*)		
£100 3½% Defence Bonds at cost	100 0 0	
		499 10 6
		£499 10 6

MEMORIAL LECTURE FUND

	£ s. d.	£ s. d.
Balance, 31st December, 1956 :—		
Cash at Bank	27 14 6	
£350 3½% Defence Bonds at cost	350 0 0	
		377 14 6
		£377 14 6

LEGACY FUND

	£ s. d.	£ s. d.
Dow Prizes		
Balance at 31st December, 1956 :—		52 10 0
£916 11s. 1d. 3½% War Loan at cost	876 5 0	
(*Market Value 31.12.56, £645*)		
£1,000 3% Savings Bonds at cost	970 0 0	
(*Market Value 31.12.56, £826*)		
£200 3½% Defence Bonds at cost ...	200 0 0	
Cash at Bank	172 14 6	
		2,218 19 6
		£2,271 9 6

ship is heartening and the Technical Committee to be formed during 1957 should prove an asset.

In addition to our technical and cultural activities the Society serves industry as a meeting place and as a means of exchange and dissemination of information about lighting. The interests of members embrace the whole process of seeing, from the physics of light sources to the physiology and psychology of vision, from economics to aesthetics, from specifications to research. The Council looks forward to a growing membership and, perhaps more difficult, a broadening programme during the coming years.

This report would be incomplete without acknowledgement of the work done throughout the year by the Secretary, Mr. G. F. Cole, and his staff. The comparatively small office in Victoria Street is always busy, providing for the increasing activity of Committees, as well as for all the clerical and financial work of the Society. On behalf of the Society, Council expresses its thanks to Mr. Cole for his skill and loyalty and for the smooth operation of the administrative work.

W. E. HARPER, *President.*
J. G. HOLMES, *Hon. Secretary.*

Appendix I

Sustaining Members

A.E.I. Lamp and Lighting Co., Ltd., Crown House, Aldwych, W.C.2.
J. Aikman and Co., Ltd., 1a, Hill Street, Edinburgh.
Aladdin Lighting Ltd., P.O. Box 3491, Johannesburg.
Allom Brothers Ltd., Lombard Road, Merton, S.W.19.
Arrow Plastics Ltd., Arrow Works, Portsmouth Road, Thames Ditton, Surrey.
Aurora Lamps Ltd., Old Kilpatrick, Glasgow.
Barlow and Young Ltd., 55, Catherine Place, London, S.W.1.
T. Beadle and Co., Ltd., 3/5, Castle Street, Hull, Yorks.
Benjamin Electric Ltd., Brantwood Road, Tottenham, N.17.
City of Birmingham Education Department, Council House, Margaret Street, Birmingham.
Bolton Corporation, Lighting Department, Marsden Road, Bolton, Lancs.
British Electrical Development Association, 2, Savoy Hill, W.C.2.
British General Electric Co. (Pty.) Ltd., Magnet House, Loveday and Anderson Streets, Johannesburg.
British Luma Co-operative Electric Lamp Society Ltd., Hardgate Road, Glasgow, S.W.1.
British Optical Association, 65, Brook Street, W.1.
Cartwright, J. T. and Sons, Ltd., 195, St. Vincent Street, Glasgow, C.2.
Central Electricity Authority, Central Electricity House, Great Portland Street, W.1.
Chance Bros. and Co., Ltd., Glass Works, Smethwick, Birmingham.
The Cinematograph Exhibitors' Association of Great Britain and Ireland, 164, Shaftesbury Avenue, London, W.C.2.
Claude Neon Lights of New Zealand Ltd., 91, Hobson Street, Auckland, C.1, New Zealand.
E. Clegg and Sons, Ltd., Shore Mills, Littleborough, Lancs.
Courtney, Pope (Electrical) Ltd., Amhurst Park Works, N.15.
R. and A. G. Crossland, Ltd., Cartbridge Lane, Walsall, Staffs.
Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2.
Cryselco, Ltd., 231, Strand, W.C.2.
George Davidson and Co., Ltd., Teams Glass Works, Gateshead-on-Tyne 8.
Hubert Davies and Co., Ltd., Hudaco House, 7, Rissik Street, Johannesburg.
Dominec (Pty.) Ltd., P.O. Box 3269, Johannesburg.
Docker Bros., Rotton Park Street, Ladywood, Birmingham 16.
Dodd and Oulton, Ltd., 8-12, Stanley Street, Liverpool 1.
Dorman and Smith Ltd., Ordsal Electrical Works, Manchester 5.
Downes and Davies, Ltd., 1-9, Stanley Street, Liverpool 1.
Drake and Gorham Wholesale Ltd., 77, Long Acre, W.C.2.
Eastern Electricity Board, Whersted, Ipswich, Suffolk.
Eastern Gas Board, Abbey Gardens, Westminster, S.W.1.
East Midlands Electricity Board, Mapperley Hall, Nottingham.

Corporation of the City and Royal Burgh of Edinburgh, City Chambers, Edinburgh 1.
Edmundsons Electric Co., Ltd., 24-30, Gillingham Street, S.W.1.
E.G.S. Company Ltd., 10-12, Trafalgar Street, Newcastle-on-Tyne 1.
Ekco-Ensign Electric Ltd., 45, Essex Street, Strand, W.C.2.
Electric Lamp Manufacturers Association, 25, Bedford Square, W.C.1.
Electric Street Lighting Apparatus Co., Ltd., The Foundry, Canterbury, Kent.
Electrical Components, Ltd., Components House, Ludgate Hill and Lionel Street, Birmingham 3.
George Ellison, Ltd., Wellhead Lane Works, Perry Bar, Birmingham 22b.
Engineering and Lighting Equipment Co., Ltd., Sphere Works, St. Albans, Herts.
Engineering Service Installations, Ltd., 258, Grays Inn Road, W.C.1.
Evans Electroselenium Ltd., Potter Street, Harlow, Essex.
The Ever Ready Co. (Great Britain) Ltd., Hercules Place, Holloway, London, N.7.
Falk, Stadelmann and Co., Ltd., 91, Farringdon Road, E.C.1.
Falks Electrical Supplies (S.A.) (Pty.) Ltd., 17, Heidelberg Road, Village Main, Johannesburg.
H. W. Field & Son Ltd., Cable Works, Station Road, Harold Wood, Essex.
Foster Electrical Supplies Ltd., Morden Road, South Wimbledon, S.W.19.
B. French, Ltd., Mill Lane, Kidderminster, Worcs.
Fulford Brown Bros. (1929) Ltd., Crystex Works, Regent Parade, Birmingham 1.
Gas Council, Gas Industry House, 1, Grosvenor Place, S.W.1.
General Electric Co., Ltd., Magnet House, Kingsway, W.C.2.
Girdlestone & Co. Ltd., 23, Davies Street, London, W.1.
Donald Grant and Sons, Ltd., St. James Place, Edinburgh, 1.
Hailwood and Ackroyd, Ltd., Beacon Works, Morley, Leeds.
W. T. Hellaby and Co., Ltd., 80, Dale End, Birmingham.
Heyes and Co., Ltd., Water Heyes Electrical Works, Wigan, Lancs.
S. H. Heywood and Co., Ltd., 2, North Parade, Parsonage, Manchester 3.
Hirst, Ibbetson and Taylor, Ltd., 47-53, Chapel Street, Salford 3, Lancs.
Hivac Ltd., Greenhill Crescent, Harrow-on-the-Hill, Middlesex.
Holland House Electrical Co., Ltd., 221, St. Vincent Street, Glasgow, C.2.
Holophane, Ltd., Elverton Street, Vincent Square, S.W.1.
Humber Ltd., Ryton-on-Dunsmore, Coventry.
Hume, Atkins and Co., Ltd., New Icknield Way, Letchworth, Herts.
Imperial Chemical Industries Ltd. (Metals Division), Kynoch Works, Witton, Birmingham 6.
Imperial Chemical Industries Ltd. (Paints Division), Wexham Road, Slough, Bucks.
Imperial Chemical Industries Ltd. (Plastics Division), Black Fan Road, Welwyn Garden City, Herts.
Inductive Appliances, Ltd., 18, Dean Street, Newcastle-on-Tyne, 1.
J. A. Jobling and Co., Ltd., Wear Glass Works, Sunderland.
James Kilpatrick and Son, Ltd., Kelvin House, River Cart Walk, Paisley.
Knightshades Ltd., Silverhill Works, Theaklen Drive, St. Leonards-on-Sea, Sussex.
Lancashire Dynamo Electronic Products Ltd., B.E.P. Works, Rugeley, Staffs.
Leeds Education Committee, Education Offices, Calverley Street, Leeds 1.
Linolite Ltd., Mill Works, Malmesbury, Wilts.
Littlewoods Pools, Central Maintenance Department, Cases Street, Liverpool 1.
Corporation of Liverpool, Town Clerk's Office, Municipal Buildings, Liverpool 2.
The Lodge Fittings Co., Ltd., 57, Albert Road, Aston, Birmingham.
London Electric Firm, Ltd., Brighton Road, South Croydon, Surrey.
London Electricity Board, 46-7, New Broad Street, E.C.2.
Joseph Lucas Ltd., Gt. King Street, Birmingham.
Luxram Electric Ltd., 72, Great Eastern Street, London, E.C.2.
Marryat & Place Ltd., 40, Hatton Garden, London, E.C.1.
Merchant Adventurers Ltd., 43, Portland Road, London, W.11.
Merseyside and N. Wales Electricity Board, Electricity House, Love Lane, Pall Mall, Liverpool.
Metallic Seamless Tube Co., Ltd., Ludgate Hill, Birmingham, 3.
Metropolitan-Vickers (S.A.) Pty., Ltd., Maritime House, Loveday Street, Johannesburg.
Midland Electric Installation Co., Cyprus Works, Upper Villiers Street, Wolverhampton.
Midlands Electricity Board, Headquarters, Mucklows Hill, Halesowen, Worcs
Morgan Crucible Co., Ltd., Battersea Church Road, S.W.11.
Mortimer Gall and Co., Ltd., 115/117, Cannon Street, London, E.C.4.
Municipal Electricity Department, Singapore.

Neon Fluorescent (S.A.) (Pty.) Ltd., P.O. Box 9101, Johannesburg.
Nettle Accessories Ltd., Harper Road, Wythenshawe, Manchester 22.
New Era Lighting Industries (Pty.) Ltd., 127, Anderson Street, Johannesburg.
Newey and Eyre, Ltd., 18, Newhall Hill, Birmingham.
North Eastern Electricity Board, Carliol House, Newcastle-on-Tyne 1.
North Western Electricity Board, Cheetwood Road, Manchester.
Oldham Corporation Surveyors and Building Committee, Lighting Dept., Gas Street, Oldham, Lancs.
Oldham & Son Ltd., Denton, Manchester.
Philips Electrical Ltd., Century House, Shaftesbury Avenue, W.C.2.
S.A. Philips (Pty.) Ltd., Upper Railway Road, Cnr. Herb Street, New Doornfontein, Johannesburg.
F. H. Pride, Ltd., Clapham High Street, S.W.4.
Progress Electric Fitting Co. (Pty.) Ltd., P.O. Box 7307, Johannesburg.
Prudential Assurance Co., Ltd., 142, Holborn Bars, E.C.1.
Albert E. Reed and Co., Ltd., 105, Piccadilly, London, W.1.
Revo Electric Co., Ltd., Britannia Works, Tividale, Tipton, Staffs.
Fred Reynolds Ltd., 230, Wellington Street, Leeds 1.
John Riley and Son (Electrical) Ltd., 281-283, Attercliffe Common, Sheffield 9.
J. Rivlin Ltd., 16/17, Brunswick Street, Leeds.
Robinson, King and British Challenge Glazing Co., Ltd., Marshgate Lane, Stratford, E.15.
Rogers, G. S. (Pty.) Ltd., 9, Leyds Street, Johannesburg.
Rowe Bros. and Co., Ltd., Pall Mall, Liverpool 3.
Rowlands Electrical Accessories, Ltd., 157, Hockley Hill, Birmingham 18.
Satchwell and Gittings, Ltd., Tantarra Electrical Works, Walsall, Staffs.
James Scott and Co., Ltd., 175, St. Vincent Street, Glasgow, C.2.
Siemens Brothers British (Pty.), Ltd., 20, Simmonds Street South, Johannesburg.
Siemens Brothers and Co., Ltd., 38-39, Upper Thames Street, E.C.4.
Sign Components, Ltd., 121-3, Camden High Street, N.W.1.
Simplex Electric Co., Ltd., Broadwell, Oldbury, Birmingham.
Simplex Electric Co. (S.A.) (Pty.), Ltd., Hassett Road, Nuffield Springs, Transvaal.
S. L. R. Electric Ltd., Welbeck Works, Welbeck Road, South Harrow, Middlesex.
S.M.D. Manufacturing Co. (Pty.) Ltd., 9, Young Road, P.O. Box 30, Pinetown, Natal.
Herman Smith Smithlite, Ltd., Empire Works, Dudley, Worcs.
Wm. Allan Smith and Co., Ltd., East Silvermills, Edinburgh 4.
W. H. Smith and Co. (Electrical Engineers), Ltd., 12, York Street, Manchester 2.
J. G. Sneath Ltd., Wallwood Street, Limehouse, London, E.14.
South Eastern Electricity Board, 10, Queen's Gardens, Hove 3, Sussex.
South of Scotland Electricity Board, 351, Sauchiehall Street, Glasgow, C.2.
South Wales Electricity Board, St. Mellons, Cardiff.
South Western Electricity Board, Electricity House, Colston Avenue, Bristol.
Southern Electricity Board, Southern Electricity House, Bath Road, Maidenhead, Berks.
Stella Lamp Co., Ltd., 37/39, Oxford Street, W.1.
W. H. Stone and Co. (Cardiff). Ltd., Service House, 16-17, Hill's Terrace, Cardiff.
Strand Electric and Engineering Co., Ltd., 24, Floral Street, W.C.2.
Strong Electric Corporation (Great Britain) Ltd., Newbourne Works, Whyteleafe, Surrey.
Wm. Sugg and Co., Ltd., Ranelagh Works, Chapter Street, S.W.1.
Thermo-Plastics Ltd., Luton Road Works, Dunstable, Beds.
Thorn Electrical Industries, Ltd., 105-9, Judd Street, W.C.1.
Thorn Electrical Industries (S.A.) (Pty.), Ltd., P.O. Box 75, Industria, Johannesburg.
F. W. Thorpe, Ltd., Thorlux Works, Welby Road, Hall Green, Birmingham 28.
Troughton and Young, Ltd., Imperial Court, Knightsbridge, S.W.3.
Tucker and Edgar, Berkeley Works, Berkeley Road, N.W.1.
Verity's, Ltd., Plume and Victoria Works, Aston, Birmingham 6.
Walsall Conduits, Ltd., Excelsior Works, West Bromwich, Staffs.
J. Walton (Electrical) Ltd., 333, Chapel Street, Salford, Lancs.
Wardle Engineering Co., Ltd., Old Trafford, Manchester.
J. M. Webber and Co., Ltd., Weblite House, 244, Tottenham Court Road, W.1.
Whitworth Electric Lamp Co., Ltd., 6-12, Gorleston Street, West Kensington, W.14.
Wokingham Plastics Ltd., Denton Road, Wokingham, Berks.
A. J. Wright (Electrical) Ltd., 67-69, Victoria Street, Liverpool 1.
Yorkshire Electricity Board, Wetherby Road, Scarcroft, Thorner, nr. Leeds.
Z. Electric Lamp and Supplies Co., Ltd., 21, Newman Street, W.1.

Appendix 2

I.E.S. Representatives on Outside Committees

NATIONAL ILLUMINATION COMMITTEE	Mr. G. F. Cole, Mr. E. C. Lennox, Mr. J. G. Holmes, Mr. L. H. McDermott, Mr. J. M. Waldram
COUNCIL FOR CODES OF PRACTICE	Mr. G. F. Cole
Codes of Practice Committee for Buildings	Mr. J. G. Holmes
Codes of Practice Committee for Electrical Engineering	Mr. W. R. Stevens
PARLIAMENTARY AND SCIENTIFIC COMMITTEE	Mr. J. G. Holmes
CITY AND GUILDS OF LONDON INSTITUTE ADVISORY COMMITTEE ON ILLUMINATING ENGINEERING	Mr. W. R. Stevens
COMMITTEES OF THE BRITISH STANDARDS INSTITUTION:	
Electric Lamps and Lampholders for Aircraft	Mr. A. G. Penny
British National Committee of the I.E.C.	Dr. J. N. Aldington
Cinematograph Industry Standards Committee	Mr. H. C. Weston
Cinematograph Electrical Equipment	Mr. S. S. Beggs
Cinema Studio Lighting, Lamps and Fittings	Mr. S. S. Beggs
Cinematograph Carbon-Arc Equipment	Dr. F. S. Hawkins
Ripple Content in Electricity Supply to Studio Equipment	Dr. F. S. Hawkins
Auditorium and Safety Lighting for Cinemas and Theatres	Mr. S. S. Beggs
Safety Signs for Cinemas and Theatres	Mr. S. S. Beggs
Stage Electrical Equipment	Mr. E. E. Faraday
Code of Practice Committee on Street Lighting	Mr. E. Stroud Mr. J. M. Waldram
Flameproof Fittings for Lighting Purposes	
Low Pressure Gas Mantles	Mr. F. C. Smith
Metal Windows	Mr. G. F. Cole
Illumination Industry Standard Committee	Mr. J. M. Waldram, Mr. J. G. Holmes, Mr. L. H. McDermott, Mr. G. F. Cole, Mr. E. C. Lennox
Nomenclature for Illumination	Mr. W. Robinson, Mr. G. F. Cole
Lighting Fittings	Mr. W. T. F. Souter, Mr. A. W. Jervis
Diffusing Materials	Dr. J. W. T. Walsh
Fittings for Double-capped Tubular Lamps	Mr. V. F. Beuttell
Watertight Fittings	Mr. G. W. S. Levey
Electric Lamps	Mr. W. T. F. Souter
Electric Lamps for Navigation Purposes	Mr. A. G. Penny
Tungsten Lamps	Mr. A. G. Penny
Discharge Lamps	Mr. A. G. Penny
Electric Signs	Mr. E. F. Martin
Road Traffic Control Signals	
Ultra-Violet Light	Mr. A. G. Penny
Colours for Signalling Purposes	Mr. J. G. Holmes
Colour Terminology	Mr. G. T. Winch
Photographic Electronic Flash Equipment	Mr. H. W. Cumming
Construction of Road Traffic Signs	Mr. F. C. Smith
Illumination of Signs	Mr. F. C. Smith
Photographic Industry Standards Committee	Mr. A. W. Gostt
Equipment for Head Protection against Radiation	Mr. H. C. Weston
Rear Lamps and Reflex Reflectors	Mr. H. F. Stephenson

XUM

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of membership:—

SUSTAINING MEMBER:—

A. G. Jorgensen (1956) (Pty) Ltd. ..... *Representative*: C. P. M. Sweeney.
409, S.A. Mutual Buildings, Corner Commissioner and Harrison Streets, Johannesburg, S. AFRICA.

CORPORATE MEMBERS:—

Carnegie, P. B. ..... 26, Oaklands, Gosforth, NEWCASTLE UPON TYNE 3.
Crole, E. ..... P.O. Box 1905, Johannesburg, S. AFRICA.
Fairweather, E. J. ..... 21, Craigleith Crescent, EDINBURGH 4.
Fallon, F. ..... 107, Lidgett Lane, LEEDS 8.
Gabarro, M. ..... Rambla Cataluna 80, Barcelona, SPAIN.
Gardener, H. J. ..... 8, Chorlton Close, Childwall, LIVERPOOL 16.
Gevert, J. ..... C/o Williamson, Balfour y Cia S.A., Casilla 118D, Santiago, CHILE.
Jochelson, M. J. ..... P.O. Box 5628, Johannesburg, S. AFRICA.
Koplick, R. W. ..... Sycamores, Devisdale Road, Altrincham, CHESHIRE.
McGowan, G. P. ..... Eastgate, Deeping St. James, Nr. Peterborough, NORTHANTS.
Pitcher, C. ..... 21, Westdown Drive, Thurmaston, LEICESTER.
Roffey, W. J. ..... 185, Cardington Road, BEDFORD.
Smyth, W. ..... 9, Market Road, Ballymena, Co. Antrim, N. IRELAND.
Stevens, B. ..... 24, Torrington Drive, Potters Bar, MIDDX.
Wegens, E. ..... 20, Hamletsgade, Copenhagen, DENMARK.
Woodward, R. C. ..... 69, Everest Avenue, Llanishen, CARDIFF.

STUDENT MEMBER:—

Collender, G. E. ..... 24, Church Road, Hadleigh, ESSEX.

TRANSFER FROM OVERSEAS TO CORPORATE MEMBERSHIP:—

Lottar, O. J. ..... Municipal Electrical Engineer, P.O. Box 4819, Haifa, ISRAEL.

A Method of Calculating Flux from an Isocandle Diagram Using a System of Discrete Points

By DOREEN SMITH, B.Sc.

Summary

It is usual in this country to publish details of an asymmetric light distribution in the form of an isocandle diagram with additional information regarding total light output or flux in the upper and lower hemispheres. Sometimes it is also necessary to give utilisation factor curves for street-lighting lanterns. It is convenient to have a method of obtaining the information for these curves by quick calculation from the isocandle diagrams.

The flux represented on the whole or part of an isocandle diagram may be calculated by reading the intensity at a number of points in a carefully chosen array and applying a simple formula. There is a number of different possible arrays and it is necessary to choose the one which is most suited to the particular calculation that has to be made. Two different types are described in this paper. One is suited to the calculation of the total light output of a lantern. The other is specially designed for the flux calculations involved in the production of utilisation factor curves.

(1) Introduction

It is customary to plot an isocandle diagram on a sinusoidal web having the property that equal areas on the web correspond to equal solid angles at the light source. The total flux represented on such an isocandle diagram may be calculated by dividing the total area of the web into n small equal areas and determining the mean intensity I within each of them. The total flux is given by $\frac{2\pi}{n} \sum_{o}^{n} I$. If each small area is of a suitable shape and size the mean intensity I may be taken as the value of the intensity at the "centre of area." Then the total flux may be determined by reading the intensity values at n discrete points on the diagram.

(2) Total Light Output

There are many ways in which the total area of the sinusoidal web may be divided into n equal areas. In Fig. 1 the lower half of the web is divided into 180 small equal areas by means of lines of constant vertical angle θ, which are drawn dotted, and lines of constant azimuth angle ϕ at 10 deg. intervals. A point is marked at the "centre of area" of each of these small areas. If this web is superposed on an isocandle diagram, the flux emitted within one quarter of a sphere from the light source may be determined by reading the intensity values at the 180 points marked and calculating $\frac{\pi}{180} \Sigma I$ for 180 values of I. The total light output of the source may be determined by making similar calculations for the flux emitted within the other three quarters of the sphere.

There are many lighting fittings which direct most of the light flux into the lower hemisphere. The web shown in Fig. 2 is useful for calculating the total light output of such fittings. The lower half of the web contains 180 points as in Fig. 1. The

Communication from the Staff of the Research Laboratories of The General Electric Company Limited, Wembley, England. The manuscript of this paper was first received on July 6, 1956, and in final form on November 16, 1956.

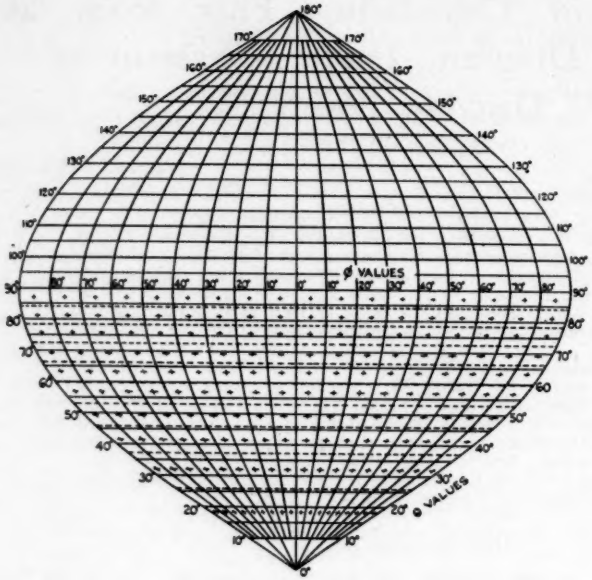

Fig. 1. Sinusoidal web with an array of 180 points in the lower hemisphere.

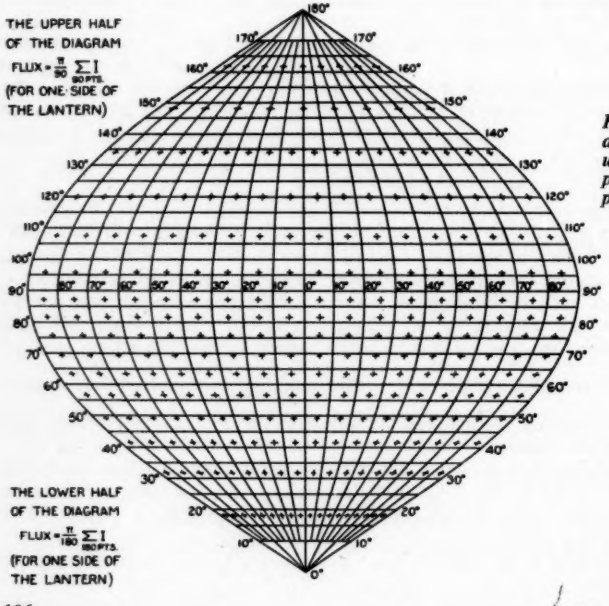
THE UPPER HALF OF THE DIAGRAM
FLUX = π/90 Σ I 90 PTS.
(FOR ONE SIDE OF THE LANTERN)
THE LOWER HALF OF THE DIAGRAM
FLUX = π/180 Σ I 180 PTS.
(FOR ONE SIDE OF THE LANTERN)

Fig. 2. Sinusoidal web with an array of 90 points in the upper hemisphere and 180 points in the lower hemisphere.

upper half of the web contains only 90 points. These are at the "centres of area" of 90 small equal areas of which the boundaries are not marked. The flux emitted from the lantern within the quarter of a sphere corresponding to the upper half of the web may be calculated using the formula $\frac{\pi}{90}\Sigma I$ for 90 values of I.

Very often it is quite adequate to use the 90-point array to calculate the flux emitted in all four quarters of the sphere, even those containing most of the flux. It depends how rapidly the light intensity varies with angle.

Fig. 3 is an example of an isocandle diagram for which there is no significant difference between the value obtained for the flux in the lower hemisphere by means of the 180-point array and that obtained by means of the 90-point array. The calculated flux values are 5,494 lumens and 5,487 lumens respectively.

This method of flux calculation has been used by the author mainly for street-lighting lanterns and other fittings which direct only a relatively small percentage of the total flux at angles below 25 deg. with the downward vertical. The 180-point array shown in Figs. 1 and 2 may be modified as indicated in Section 4 so that the points are more evenly spaced at the bottom of the web. Alternatively, the array of points described in Section 3 and illustrated in Fig. 5 may be used for light distributions in which a relatively large percentage of the total flux is directed below 25 deg. with the downward vertical.

(3) Utilisation Factors of Streetlighting Lanterns

The utilisation factor of a streetlighting lantern depends on the road width, mounting height, and "overhang." It is often desired to produce graphs from which the utilisation factor can be deduced for a road of any width with any lantern mounting arrangement. Such a graph gives the percentage of the lamp light output which falls

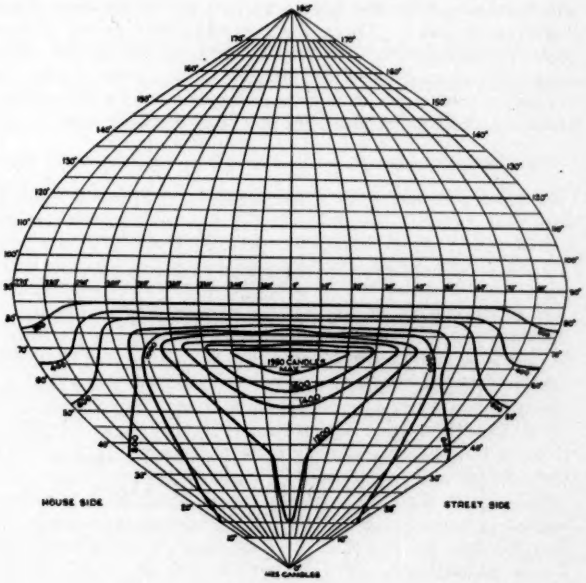

Fig. 3. Isocandle diagram for cut-off sodium lantern.

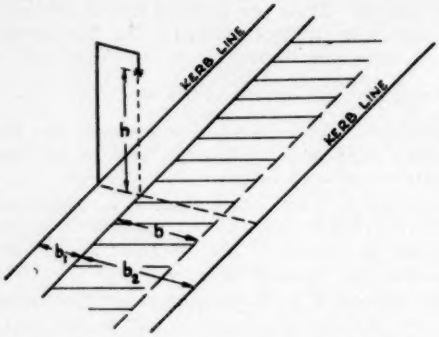

Fig. 4.

on a strip of road parallel to the kerb, bounded by a line immediately under the lantern and another line parallel to it. The percentage of the lamp light output is plotted against b/h where b is the width of the strip and h is the mounting height of the lantern. This is illustrated in Fig. 4. If the lantern has a non-axial light distribution it is necessary to plot two graphs, one for the "house side" and one for the "street side" of the lantern.

The kerb line and lines parallel to the kerb on the street lie in "great circles" about the lantern. Lines corresponding to such "great circles" may be plotted on the sinusoidal web on which the isocandle diagram of the lantern is drawn. These lines meet at the centre of the web; each corresponds to a certain b/h value.

Fig. 5 shows the outline of a sinusoidal web in which the lower half is divided into eighteen equal areas by means of the lines for which $b/h = 0$, 0.176, 0.364, 0.577, 0.839, 1.19, 1.73, 2.75, and 5.67. Each of these eighteen areas is then sub-divided into ten smaller areas, with the points to be used in the flux calculations marked at their "centres of area." There are two additional points marked within the areas at the centre of the diagram. These areas are long and narrow and the mean intensity in each cannot be assumed to be the intensity at the centre of area. The intensity value assigned to each of these areas should be the mean of the three intensity values read at the three points marked. The flux on the road between the lines for which $b/h = 0$ and

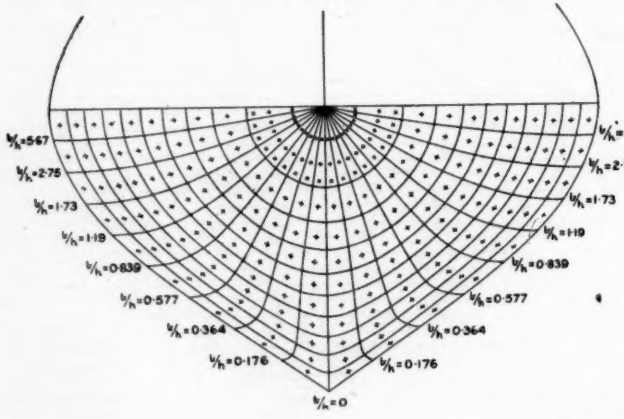

Fig. 5. An array of points for calculating utilisation factors.

$b/h = 0.839$, for example, is $\frac{\pi}{180}\Sigma I$ for 40 values, the values of I for the four areas nearest to the centre of the diagram each being taken as the mean of three values. For most streetlighting lanterns the isocandle diagram represents the light distribution on either side of the lantern and so the flux on the road is given by 2 x $\frac{\pi}{180}\Sigma I$ for the appropriate number of I values.

Using this method the percentage of the lamp light output falling on the road can be determined for eight finite values of b/h and $b/h = \infty$. The intervals in b/h are rather large where b/h is greater than 1.73, and so in plotting a utilisation factor curve it is generally necessary to plot the value for $b/h = 5.67$ in order to obtain the shape of the graph even if this value is not required on the final diagram.

A utilisation factor curve was obtained for a small sodium lantern using the array of points in Fig. 5 in conjunction with the isocandle diagram. This curve was compared with one obtained by planimetry of the same isocandle diagram. At the b/h value of 0.577 the percentage lamp light output values obtained by the two methods were 15.75 per cent. and 15.6 per cent. At all b/h values higher than this the agreement between the two methods was equally good. When the subsidiary points in the centre of the diagram in Fig. 5 were ignored the percentage lamp light output value calculated for $b/h = 0.577$ was 15.9 per cent. instead of 15.75 per cent.

A quick inspection of the intensity distribution within the central small areas generally indicates whether or not the subsidiary points must be used in order to obtain a result of the required accuracy.

(4) Calculations for Figs. 1 and 2

It is necessary to determine the values of θ at which the dotted lines must be drawn in Fig. 1 in order to divide the lower half of the web into equal areas.

Consider the sphere which corresponds to the sinusoidal web. The lower half of the sphere must be divided into 10 zones, each subtending a solid angle of $\frac{2\pi}{10}$ steradians at the centre. If θ_1 and θ_2 are the vertical angles defining a zone, the solid angle subtended by the zone at the centre of the sphere is $2\pi(\cos\theta_1 - \cos\theta_2)$ steradians. If this solid angle is to be $\frac{2\pi}{10}$ steradians, then θ_1 and θ_2 must have values such that $(\cos\theta_1 - \cos\theta_2) = 0.1$. Thus the required 10 zones will be those defined by the angles θ whose cosine values are 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1 and 0. These angles are 0, 25.85, 36.9, 45.6, 53.1, 60.0, 66.4, 72,55, 78.45, 84.25 and 90.0 deg. These are the values of θ at which the dotted lines are drawn on the web in Fig. 1.

Now it is necessary to determine the position of the points which are at the "centres of area" of the small areas bounded by the dotted lines and the lines of constant ϕ for $\phi = 0, \pm 10, 20, 30$ deg., etc. Clearly the points have the ϕ values $\pm 5, 15, 25$ deg., etc. They must also lie on the lines of constant θ which would divide the area between each pair of consecutive dotted lines into two equal areas. Therefore they must lie on lines of constant θ for which cosine $\theta = 0.95, 0.85, 0.75, 0.65, 0.55, 0.45, 0.35, 0.25$ and 0.15; i.e., they must have θ values of 18.2, 31.8, 41.4, 49.45, 56.65, 63.25, 69.5, 75.5, 81.35 and 87.15 deg. These angles are the Russell angles[1] which are often used in flux calculations for symmetrical light distributions.

Similarly, the upper half of the web may be divided into 90 equal areas by means of constant θ lines for values of θ given by $\cos(180 - \theta) = 0, 0.2, 0.4, 0.6, 0.8$ and 1.0, and constant ϕ lines for $\phi = 0, \pm 10, 20, 30$ deg., etc. The "centres of area"

of these 90 areas lie at the ϕ values $\pm$ 5, 15, 25 deg., etc., on the lines of constant θ for values of θ given by $\cos(180 - \theta) = 0.1$, 0.3, 0.5, 0.7 and 0.9, i.e., $\theta = 95.75$, 107.45, 120.0, 134.4 and 154.15 deg. An array of points marked at these θ, ϕ values is not suitable for flux calculation as the points are not well spaced near the top of the web. The array may be modified, as in the upper half of Fig. 2, by replacing the 18 points on the constant θ line for $\theta = 154.15$ deg. with nine points on each of the lines of constant θ for $\theta = 148.2$ and 161.8 deg. at the ϕ values 0, $\pm$ 20, 40, 60 and 80 deg. The positions of these points are obtained by considering the area of the web above the constant θ line given by $\cos(180 - \theta) = 0.8$ divided into 18 equal areas by means of the constant θ line given by $\cos(180 - \theta) = 0.9$ and the constant ϕ lines for $\phi = \pm$ 10, 30, 50, 70 and 90 deg. The points are at the " centres of area " of these 18 small areas.

Similarly, the array of 180 points shown in the lower half of the sinusoidal web may be modified by replacing the 18 points on the constant θ line for $\theta = 18.2$ deg. by nine points on each of the constant θ lines for $\theta = 12.8$ and 22.3 deg. at the ϕ values 0, $\pm$ 20, 40, 60 and 80 deg. This is necessary only if a large percentage of the flux is directed between the vertical angles 0 and 25 deg.

(5) Calculations for Fig. 5

In Fig. 6, XOX′ is a line on the road parallel to the kerb, O being immediately under the lantern. OZ is a line across the road at 90 deg. to XX′, APA′, BQB′, CRC′, etc., are lines parallel to the kerb for which $b/h = \tan\alpha$, $\tan 2\alpha$, $\tan 3\alpha$, etc. These lines intersect OZ at P, Q, R, etc. In practice it is found convenient to let $\alpha = 10$ deg. Then the strip of road between any two consecutive lines, CC′ and DD′ for example, will subtend a solid angle of $\pi/9$ steradians at the light source.

Lines on the sinusoidal web corresponding to PA′, QB′, RC′, etc., meet at the

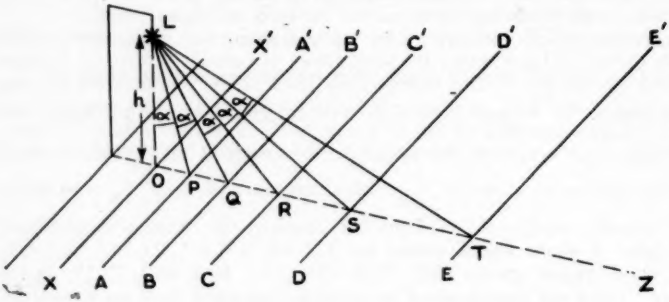

Fig. 6.

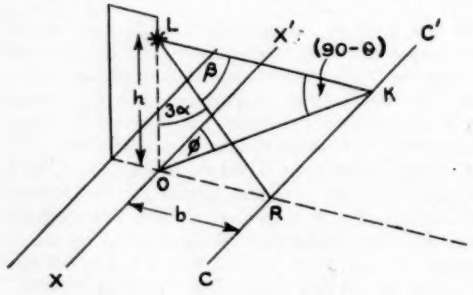

Fig. 7.

Table I

Pairs of θ, φ values which satisfy the relationship $b/h = \sin\phi \tan\theta$ for the b/h lines shown in Fig. 5

$\tan^{-1}b/h$ deg.	b/h	θ, φ values															
10	.176	θ	90	80	70	60	50	40	30	20	15	11.5	10.6	10			
		φ	0	1.8	3.7	5.85	8.5	12.15	17.8	28.95	41.15	60	70	90			
20	.364	θ	90	80	70	60	50	40	30	22.8	20.65	20					
		φ	0	3.7	7.6	12.15	17.8	25.7	39.1	60	75	90					
30	.577	θ	90	80	70	60	50	40	33.7	30.85	30						
		φ	0	5.85	12.15	19.45	28.95	43.5	60	75	90						
40	.839	θ	90	80	70	60	50	44.1	41.0	40							
		φ	0	8.5	17.8	28.95	44.75	60	75	90							
50	1.192	θ	90	80	70	60	54.0	51.0	50								
		φ	0	12.15	25.7	43.5	60	75	90								
60	1.732	θ	90	84.25	78.85	73.9	69.65	66.15	63.45	61.5	60.4	60					
		φ	0	10	20	30	40	50	60	70	80	90					
70	2.747	θ	90	86.4	82.9	79.7	76.85	74.4	72.5	71.1	70.25	70.0					
		φ	0	10	20	30	40	50	60	70	80	90					
80	5.671	θ	90	88.25	86.55	84.95	83.55	82.3	81.3	80.6	80.15	80					
		φ	0	10	20	30	40	50	60	70	80	90					

Table 2

Pairs of θ, ϕ values which satisfy the relationship $\sin\beta = \cos\phi \sin\theta$ for the constant β boundary lines in Fig. 5

β (deg.)	θ, ϕ values										
5.75	θ	90	80	70	60	50	40	30	20	10	5.75
	ϕ	84.25	84.15	83.9	83.35	82.5	81.05	78.45	73.0	54.85	0
11.55	θ	90	80	70	60	50	40	30	20	15	11.55
	ϕ	78.45	78.3	77.7	76.65	74.85	71.85	66.4	54.2	39.4	0
17.45	θ	90	80	70	60	50	40	30	20	17.45	
	ϕ	72.55	72.25	71.4	69.75	66.95	62.2	53.15	28.7	0	
23.6	θ	90	80	70	60	50	40	30	25	23.6	
	ϕ	66.4	66.05	64.8	62.5	58.5	51.5	36.85	18.8	0	
30.0	θ	90	80	70	60	50	40	35	32.15	30	
	ϕ	60.0	59.5	57.85	54.75	49.25	38.95	29.35	20	0	
36.85	θ	90	80	70	60	50	40	36.85			
	ϕ	53.15	52.45	50.3	46.15	38.45	21.05	0			
44.4	θ	90	80	70	60	50	45	44.4			
	ϕ	45.6	44.7	41.85	36.05	24.0	8.10	0			
53.15	θ	90	80	70	60	55	53.15				
	ϕ	36.85	35.7	31.65	22.5	12.4	0				
64.15	θ	90	85	80	75	70	65	64.15			
	ϕ	25.85	25.4	24.0	21.3	16.75	6.8	0			

Table 3

Pairs of θ, φ values which satisfy the relationship $\sin\beta = \cos\phi \sin\theta$ for the constant β lines which locate the points marked + in Fig. 5

β (deg.)	θ, φ values											
2.85	θ	90	80	70	60	50	40	30	20	10	5	2.85
	φ	87.15	87.1	86.95	86.7	86.25	85.55	84.25	81.6	73.25	55.0	0
8.65	θ	90	80	70	60	50	40	30	20	15	10	8.65
	φ	81.35	81.25	80.8	80.0	78.7	76.5	72.55	64.0	54.6	30.25	0
14.5	θ	90	80	70	60	50	40	30	20	15	14.5	
	φ	75.5	75.3	74.55	73.20	70.95	67.10	60.0	43.05	15.0	0	
20.5	θ	90	80	70	60	50	40	30	25	20.5		
	φ	69.5	69.2	68.15	66.15	62.8	57.0	45.55	34.1	0		
26.75	θ	90	80	70	60	50	40	35	30	26.75		
	φ	63.25	62.8	61.4	58.7	54.05	45.55	38.3	25.85	0		
33.35	θ	90	80	70	60	50	40	35	33.35			
	φ	56.65	56.05	54.15	50.55	44.1	31.15	16.45	0			
40.55	θ	90	80	70	60	50	45	41.3	40.55			
	φ	49.45	48.7	46.25	41.35	31.95	23.2	10	0			
48.6	θ	90	80	70	60	55	50	48.6				
	φ	41.4	40.4	37.05	30.0	23.7	11.75	0				
58.2	θ	90	80	70	65	60	58.2					
	φ	31.8	30.35	25.25	20.35	11.0	0					
66.45	θ	90	85	80	75	70	66.45					
	φ	23.55	23.05	21.45	18.35	12.7	0					
71.8	θ	90	85	80	75	72.5	71.8					
	φ	18.2	17.5	15.3	10.4	5	0					
79.5	θ	90	85	82.5	80	79.5						
	φ	10.5	9.2	7.4	3.25	0						

centre of the web and divide one quadrant into nine equal areas, each area representing a solid angle of $\pi/18$ steradians. To plot a line on the web corresponding to RC′, for example, it is necessary to determine the relationship between the vertical angle θ and the azimuth angle ϕ for any point on the line.

It can be deduced from Fig. 7 that for any point K on RC′, $b/h = \sin\phi \tan\theta$, i.e., tan 30 deg. $= \sin\phi \tan\theta$.

The results of calculations for a number of pairs of θ, ϕ values for $b/h = \tan$ 10 deg., tan 20 deg., tan 30 deg., etc., are given in Table 1.

Having plotted the lines PA′, QB′, RC′, etc., on the sinusoidal web, it is necessary to divide each of the areas between these lines into ten smaller equal areas.

In Fig. 8, YY′ is a line through L parallel to the line XX′ shown in Fig. 6. The great circles YMY′ and YNY′ in Fig. 8 identify two consecutive lines of the family such as DD′ and CC′ in Fig. 6. It is necessary to divide the segment between YMY′ and YNY′ into small elements each having a solid angle of π /180 steradians. Consider the area A marked on the surface of the sphere in Fig. 8. If this area subtends a solid angle of $\pi/180$ steradians at the centre of the sphere then $(\sin\beta_2 - \sin\beta_1) = 0.1$. This expression is derived in a way similar to that for calculating Russell angles, considering Y′ as the pole of the sphere. Thus the segment between YMY′ and YNY′ may be divided into the twenty desired elements if they are defined by the angles β for which $\sin\beta = 0, \pm 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9$ and 1.0. These are the angles $0, \pm 5.75, 11.55, 17.45, 23.6, 30.0, 36.85, 44.4, 53.15, 64.15$ and 90 deg. If lines of constant angle β are plotted on the sinusoidal web for the positive values of β given here they will divide each of the areas between consecutive b/h lines into ten small equal areas. Note that only one half of the segment is represented on the web.

To plot a line of constant angle β on the sinusoidal web it is necessary to determine the relationship between θ, ϕ and β. It may be deduced from Fig. 7 that $\sin\beta = \cos\phi \sin\theta$. Pairs of θ, ϕ values which satisfy this relationship for the above values of β are given in Table 2.

Now it is necessary to determine the positions of the points which are at the "centres of area" of the 180 small equal areas bounded by constant b/h lines and constant β lines. These points will lie midway between the b/h lines and on lines of constant angle β for which $\sin\beta = 0.05, 0.15, 0.25, 0.35, 0.45, 0.55, 0.65, 0.75, 0.85$ and 0.95. The angles having these sine values are 2.85, 8.65, 14.5, 20.5, 26.75, 33.35, 40.55, 48.6, 58.2 and 71.8 degrees. Pairs of θ, ϕ values which satisfy the relationship $\sin\beta = \cos\phi \sin\theta$ for these values of β are given in Table 3.

If the central small areas are subdivided into three smaller equal elements then the "centres of area" of these small elements will lie on the lines of constant angle β.

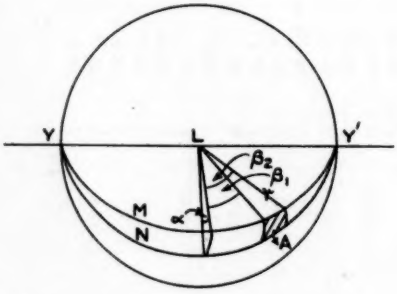

Fig. 8.

where sin $\beta = 0.9167$, 0.95 and 0.9833, i.e., where $\beta = 66.44$ deg., 71.8 deg. and 79.5 deg. Pairs of θ, ϕ values which are necessary for plotting these lines of constant β are also given in Table 3.

Reference

(1) Russell, A., *Inst. El. Eng. J.*, **32**, p. 631 (1903).

Printed by
ARGUS PRESS, LTD.,
Temple-avenue and
Tudor-street,
London, E.C.4,
England.